DØNote xxxx

Channel-by-channel t_0 Calibration of the Central Muon BC-layer Scintillation Counters

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1 Introduction

A-layer scintillation counters were calibrated in December 2002 using data collected from root tuples. Unfortunately, BC-layer counters could not be calibrated at that time using the same method. BC-layer counters have two photomultiplier tubes (PMTs) each, and roottuples contained only averages of the times from each tube. Thus roottuples could not be used to calibrate individual PMTs in the BC-layer counters (see [2]).

This note describes the calibration of BC-layer counters, channel-by-channel, using data collected from data available in raw datafiles. It also describes methods used after calibration both to verify proper t_0 calibration and to provide subsequent calibration data.

2 Procedure for Determining the t_0s

2.1 Skimming data from raw datafiles

The input files for the initial calibration were all from a single run, 179618, taken on 4 August 2003. This run was chosen because it had a large number of events and was a good muon run. (270 nb^{-1}were delivered for this run.)

Thumbnails retain only the average of the two individual PMT times (or the earlier of the two if they are incompatible). Raw data, however, contains times recorded for each individual PMT. Since MuoExamine code runs on rawdata, it was chosen for use in this analysis with the following modifications:

•The MuoExamine.cpp file was modified to allow analysis of multiple runs, and

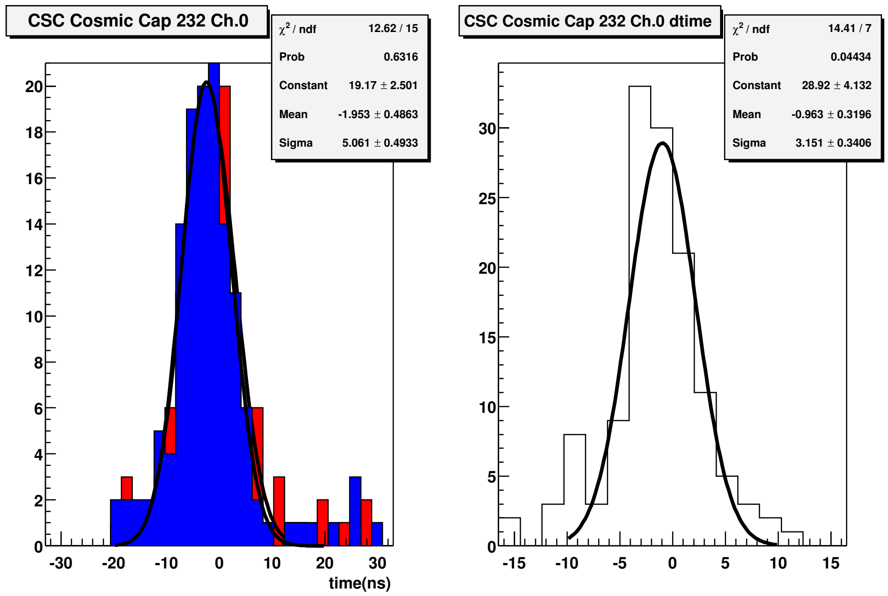
•The CMSCHistograms.cpp and .hpp files were modified to record hits for each individual PMT of each scintillation counter in the BC-layer.

Data for each counter was recorded in three histograms: one histogram for each of the two PMTs containing times recorded for each hit, and a third histogram containing the difference in times between the two PMTs. All code used for this part of the analysis can be found at: /work/tardis-clued0/harringt/tzero_root/muo_examine/.

To reduce background, only hits for which both PMTs fired were used. In addition, only those events which had muons passing at Level 2 and jets passing at Level 3 were selected. These triggers are listed below and can also be found in the TriggerSelectPkg.rcp file:

- MT10_JT20_L2M0
- MU_JT20_L3M0
- MU_JT25_L2M0
- MU_JT20_MET10
- MU_JT15_L2M0
- MU_JT15_L3M0
- MU_JT20_L2M0

Figure 1: Histograms for typical counter



2.2 Plot data

Histograms were fit to gaussians and output to a postscript file located at /home/harringt/tzero_analysis/179618_20_Nov/t0.ps. The two histograms containing PMT times were displayed on the same plot for each counter. This did make it somewhat difficult to see the histograms in cases in which time differences were very small, but it made it readily apparent when there were large time differences. See figure 1 for a typical counter's results. The first histogram shows the time distributions for both PMTs. The second histogram shows the distributions of the differences between the two PMT times for each scintillator hit.

Most counters had results very similar to that shown in figure 1. The counter with the two largest time difference between PMTs are shown in figures 2 and 3.

2.3 Calculate t_0 corrections

The standard Gaussian fit available in root was used to calculate the mean times for each counter's PMT. These means, along with the errors in the fits,

Figure 2: Counter with largest time difference prior to calibration

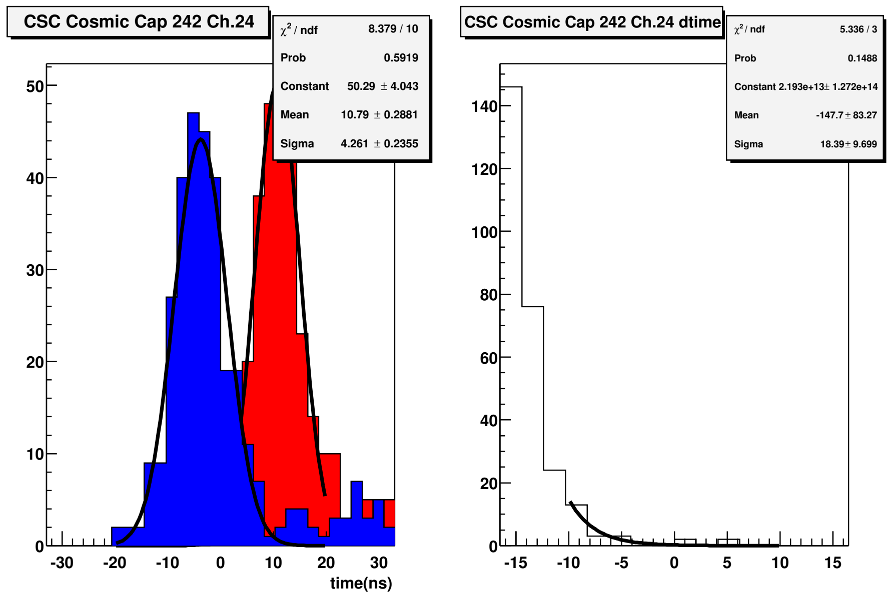
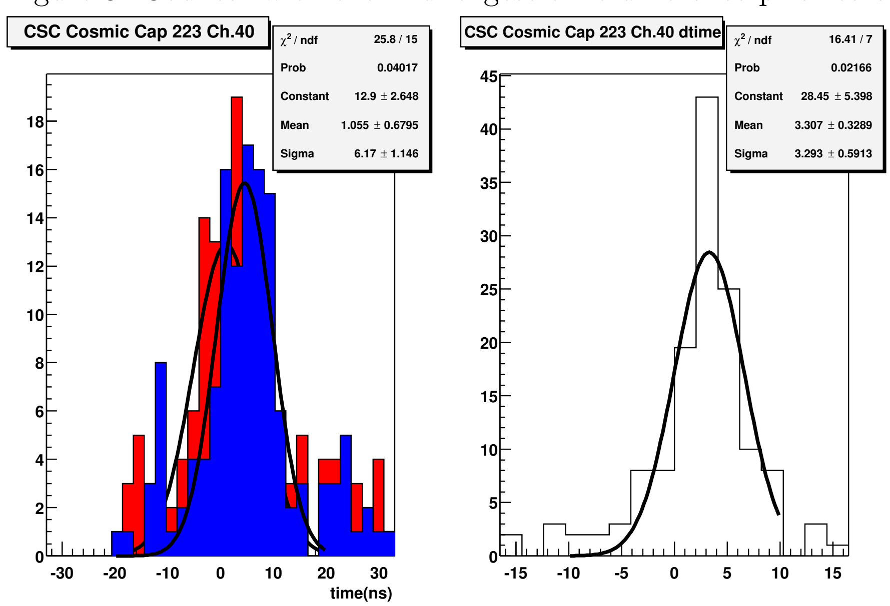


Figure 3: Counter with the 2nd largest time difference prior to calibration



were then output to a data file (tzeroC.dat). The histograms containing time differences between PMTs for each counter were also fit to Gaussians, and the data was recorded in an additional data file (tzeroCdiff.dat). Both data files, along with the individual counter histograms, are located on clued0 at: /home/harringt/muo_examine_p14.06.00/179618_20_Nov/.

Roughly 35 percent had Gaussian fits to at least one of the PMT's histograms with errors larger than 1 ns (figures 4 and 5). These bad fits were due primarily to poor statistics in octants 5 and 6 near the detector centerline where scintillation coverage is inadequate for triggering. Besides these, some additional counters near the top of the DØ detector and side walls also had poor statistics, presumably due to higher cosmic backgrounds and/or backscattering.

For roughly 50 counters, only one of the PMTs had a good fit. For these counters, the histograms containing time differences between the counter's PMTs were used. If the histogram looked reasonable and had a good Gaussian fit, the fit value was combined with the one good PMT's time to arrive at a value for the other PMT. This data was used to provide t_0 corrections for an additional 10 percent of the counters.

For the remaining 25 percent, there was insufficient data to justify doing a correction to the t_0s already in use. Most of these counters were in octants 5 & 6 in the region for which trigger coverage is less complete.

Values obtained as described here were added to existing t_0s, and subsequently rounded to the nearest 0.25 ns. These values were downloaded just prior to the first physics runs taken on 22 November 2003.

3 Results of t_0 Calibration

Data was analyzed using similar methods to determine the effect of the download using several runs from the first two weeks of taking data. These runs are itemized here with dates and integrated luminosities:

- 185576 - 11/24/2003, 94 nb^{-1}
- 185797 - 11/27/2003, 103 nb^{-1}
- 185799 - 11/27/2003, 93 nb^{-1}
- 185800 - 11/27/2003, 81 nb^{-1}
- 185801 - 11/27/2003, 69 nb^{-1}
- 185891 - 12/01/2003, 192 nb^{-1}

It was found during this analysis that histogram fits were better with larger bin sizes. Bin sizes were doubled not only for the analysis of new data, but also for re-analysis of run 179618 to allow proper comparison.

To compare data before and after the download, histograms were created using the means calculated for each PMT. (Those means with errors greater than 1 ns were excluded from these histograms.) Figures 4 and 5 show these histograms for the C- and B-layer counters separately. They were kept separate because most of the B-layer counters are in octants 5 & 6, for which there were low statistics.

For each plot, the dashed line shows the distribution of corrected t_0s prior to calibration. The solid line shows the distribution after the download of new t_0s. All histograms are normalized to unity to allow for proper comparison of distributions.

Figure 4: Mean values of times for all C-layer PMTs, before and after calibration, with Gaussian fits

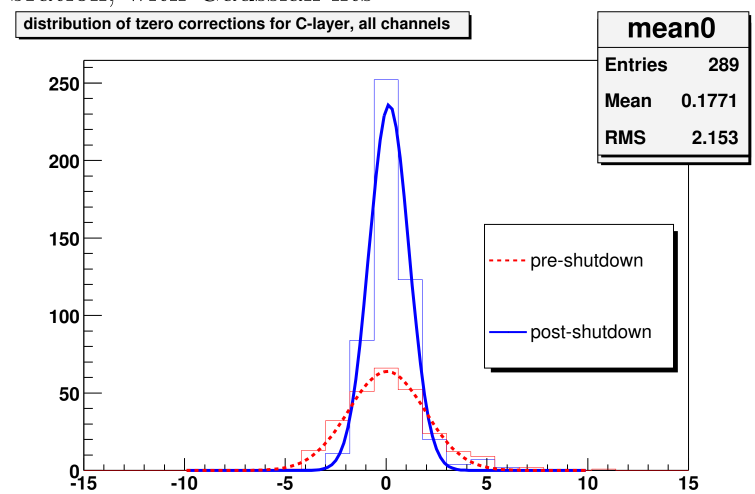
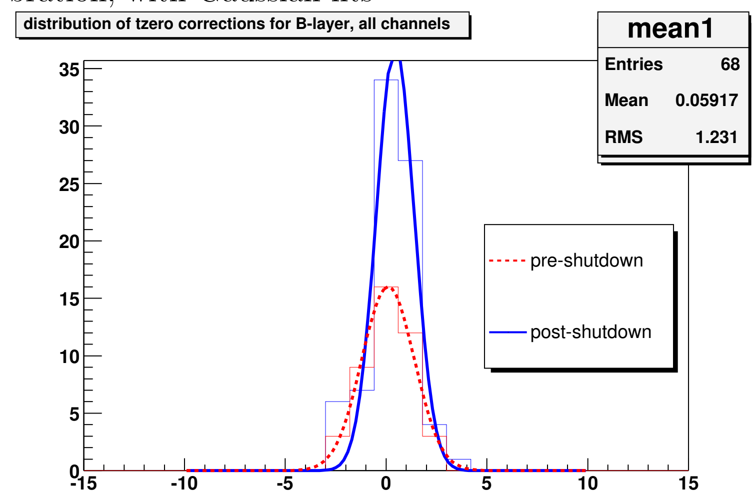
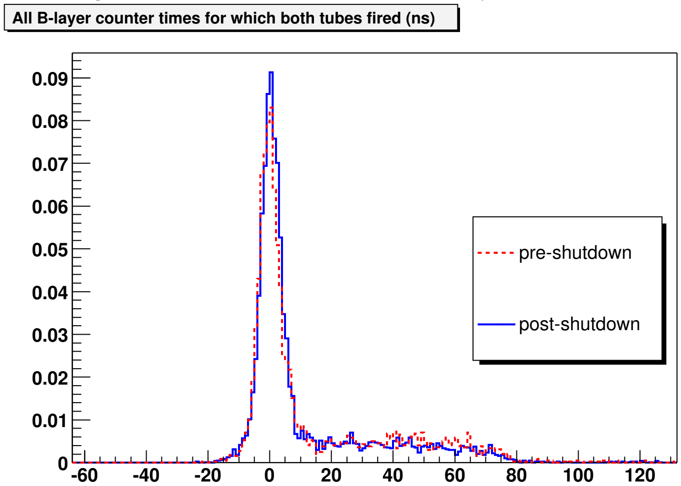


Figure 5: Mean values of times for all B-layer PMTs, before and after calibration, with Gaussian fits



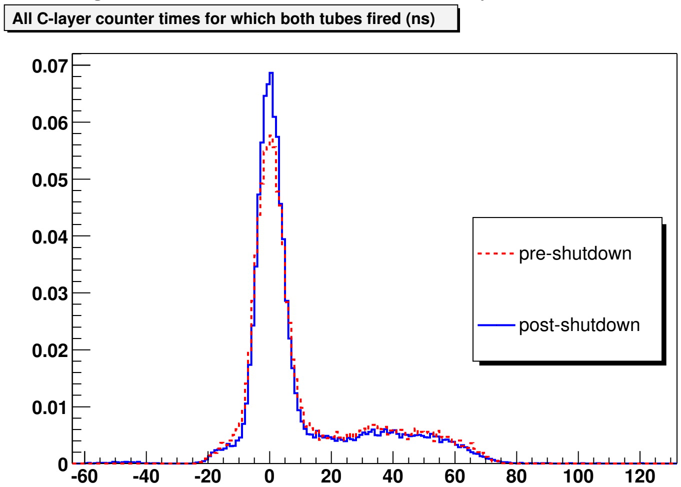
For counters in both the B- and C-layer, the new values are clearly centered more tightly around zero.

Figure 6: All times for all B-layer PMTs for events passing trigger



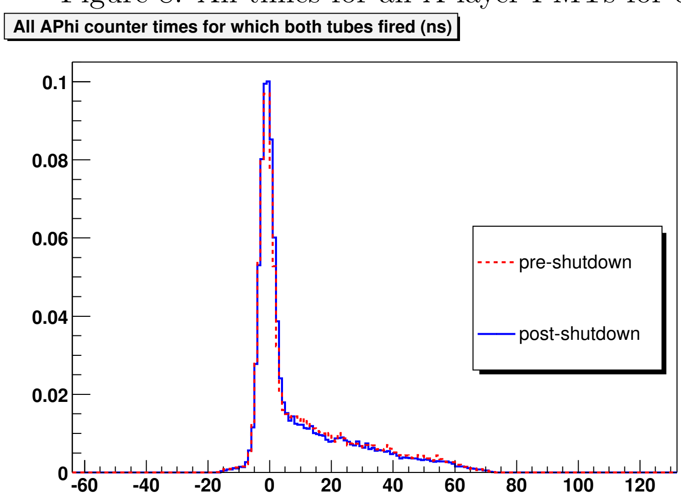
To see the effect on overall data, figures 9, 8, 6, and 7 are included.

Figure 7: All times for all C-layer PMTs for events passing trigger



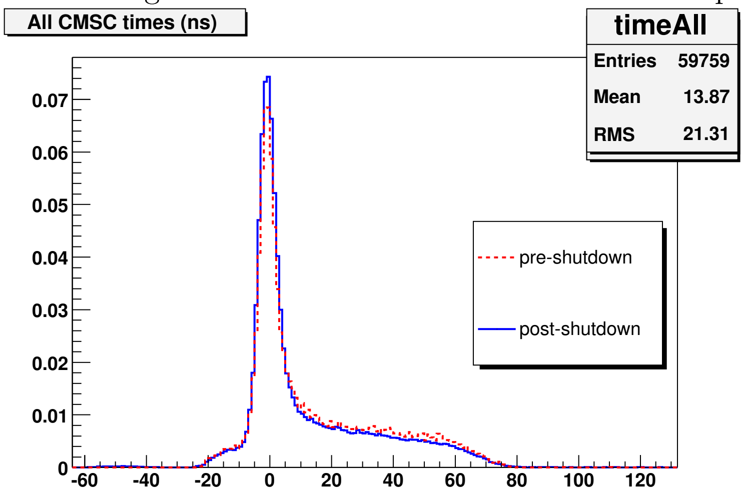
For both B- and C-layer counters, the peak for the solid line near 0 ns is larger, indicating hits centered more tightly about 0 than before.

Figure 8: All times for all A-layer PMTs for events passing trigger



A-layer hits show little change, which is expected since no A-layer counters were calibrated.

Figure 9: All times for all PMTs for events passing trigger



The plot for all PMT times for all layers shows the overall effect for events passing the triggers listed before.

Finally, figures 10 and 11 show the changes to the typical and worst counters shown earlier.

Figure 10: Histogram for typical counter after calibration

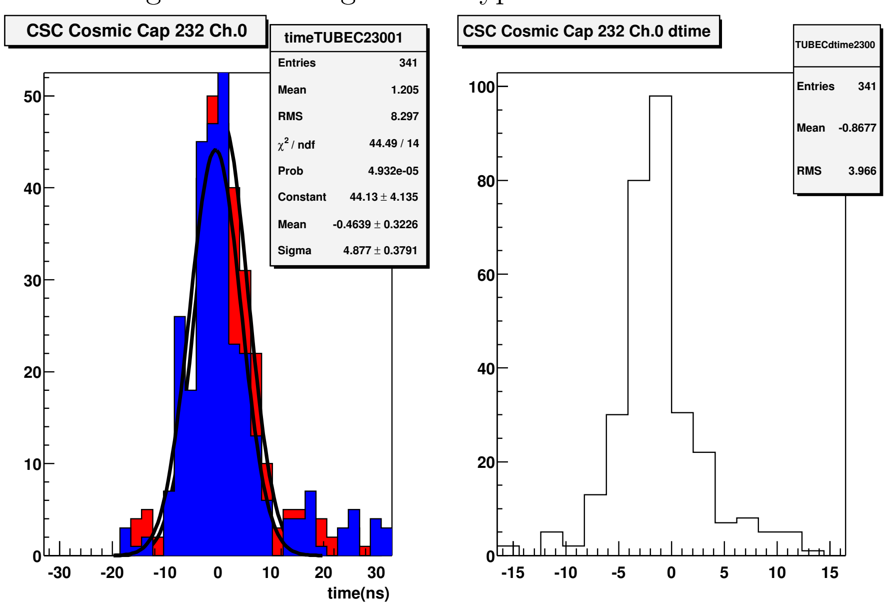
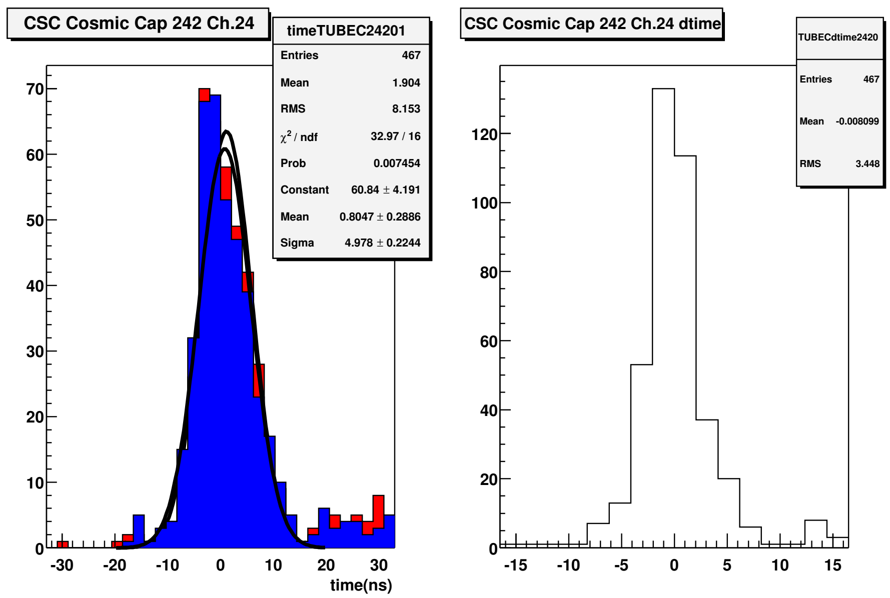


Figure 11: Counter after calibration with largest pre-calibration time difference



4 Z $\rightarrow \mu\mu$ data

There are two disadvantages of using raw data to characterize the results of calibrating t_0 for individual PMTs. The first is the difficulty in obtaining a useful parameter that clearly shows the improvement. While the width of the peak at 0 ns in the time distributions would be a good measurement, this peak contains a large fraction of background cosmic events. Cosmic events are hard to remove directly from raw data.

The second reason is that most analyses are done using thumbnails. As mentioned earlier, thumbnails contain averages of the 2 PMT times for each counter. In addition to this, B- and C-layer hits are often combined into one BC-layer time. A calibration to individual PMT t_0s may not even show up in thumbnails.

For these reasons, thumbnails were used as a final characterization of the results of the t_0 calibration.

Z $\rightarrow \mu\mu$ events were chosen to get a sample of events with a reasonably low level of cosmic muons. Events from thumbnails were chosen which met the following criteria:

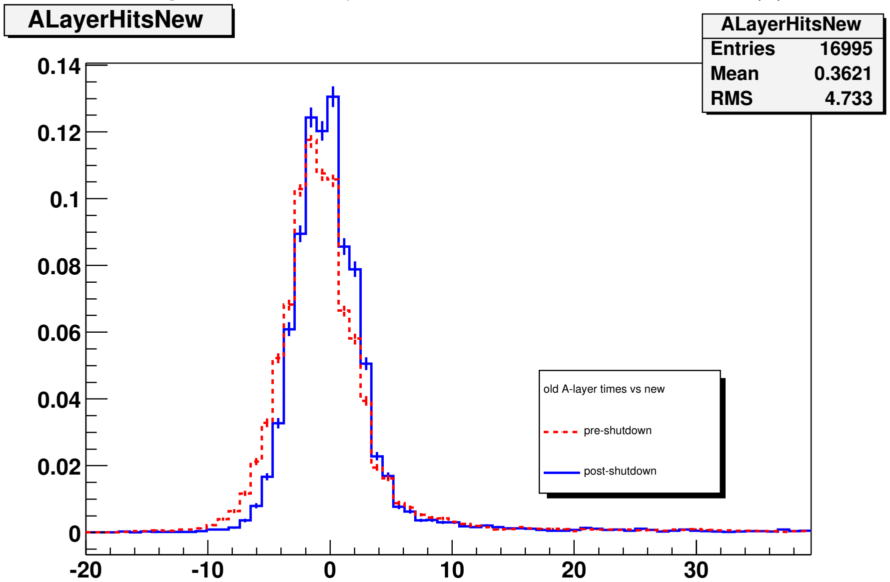
- 2 muons with $p_T \geq 8$ GeV
- opposite charge
- z of PCA within 5 cm
- 70 $\leq$ reconstructed Z mass $\geq$ 110

Run 185571 was taken after the calibration and was used as the cutoff for this analysis.

Four plots were created, figures 12, 13, 14, and 15. The first 2 show the changes in distributions for scintillator hits in the A-layer and BC-layer, respectively. One sees a qualitative improvement in the BC-layer time distribution for these Z $\rightarrow \mu\mu$ events. The values are centered more closely around zero. A gaussian fit gives a mean value of 0.32 ns, which is reasonable for a first calibration and is expected to improve with the next calibration.

The third plot shows the change to cosmic cut efficiencies before and after calibration. This is not intended to be a thorough study of cosmic cut efficiencies. Clearly, the cosmic cut efficiency is strongly analysis-dependent, as further cuts to reduce cosmic background would have had a large effect on

Figure 12: A-layer Scintillator times for Z $\rightarrow \mu\mu$ events



the cosmic cut efficiency. This was done just to get a general idea of how the t_0 calibration might affect cosmic cut efficiencies for a non-specific analysis.

The cosmic cut efficiency for a particular value of the cosmic cut was calculated in the following way:

$$efficiency = \frac{N_{loose} - N_{tight}}{N_{loose}}$$

where N_{loose} is the number of events before the cosmic cut, and N_{tight} is the number of events after.

Events passed the cosmic cut if either the A-layer time or the BC-layer time is smaller in magnitude (in ns) than the cosmic cut value.

Figure 13: BC-layer Scintillator times for Z $\rightarrow \mu\mu$ events

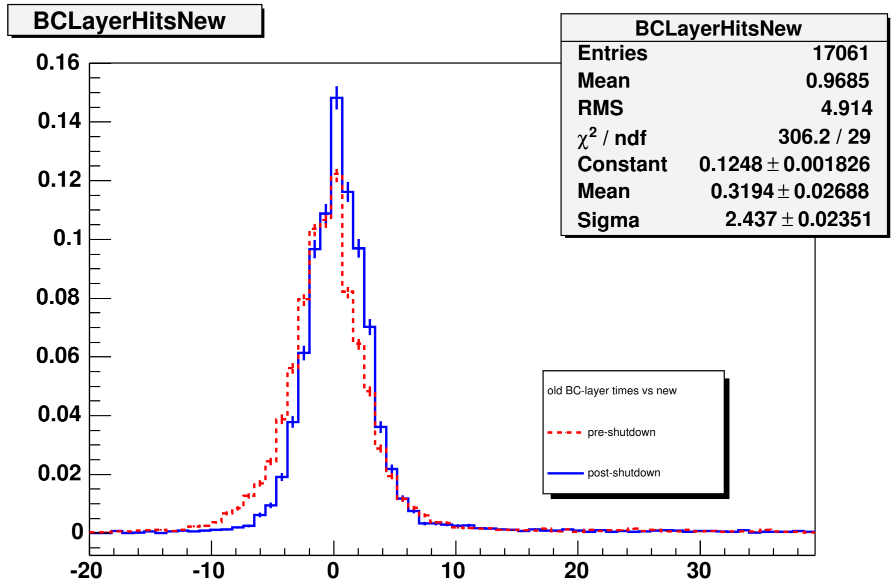


Figure 14: Cosmic cut efficiencies vs cosmic cut value for Z $\rightarrow \mu\mu$ events

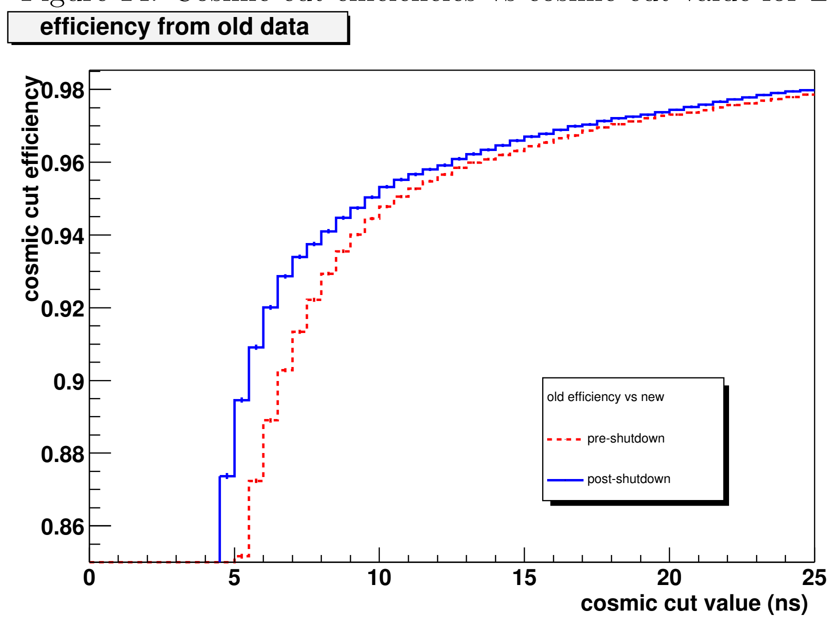
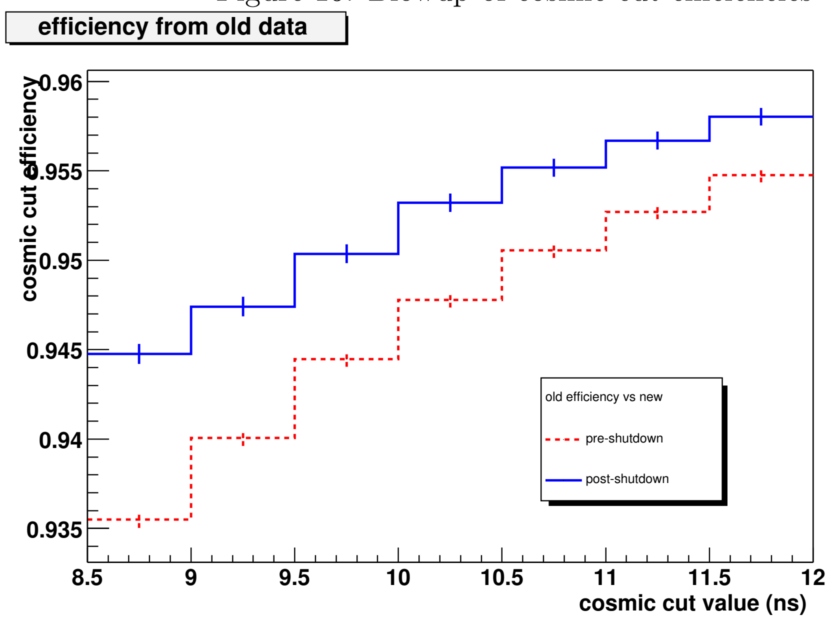


Figure 15: Blowup of cosmic cut efficiencies



5 Outlook

The calibration seems to have given a minor improvement in the ability to cut cosmics, as seen in the cosmic cut efficiency plots.

The data collected from the 6 runs immediately after the November shutdown provides t_0 values with very high precision. Unfortunately, due to the incomplete trigger coverage in octants 5 and 6, we had poor statistics for B-layer counters. With the addition of the B- and C-hole counters in trigger version 13, this problem no longer exist. Over the shutdown ending in March 2004, a special run was conducted using triggers that included the hole counters. This data will be used to obtain t_0 corrections for octants 5 and 6. New t_0 values are expected to be downloaded with the implementation of trigger version 13.

6 Acknowledgments

Thanks to the many people who helped with understanding the finer subtleties of the muon system, including Darien Wood, Tom Diehl, and Gaston Gutierrez. Thanks also to Emanuela Barberis and Dennis Schpakov for their help in the analysis.

References

[1] "The DØ Upgrade, the Detector and its Physics", Fermilab Pub-96/357-E.

[2] Chadd Bailey *et al*, DØNote 4291, Channel-by-channel Calibration of the Central Muon Scintillators, December 13, 2002.

[3] "LED Pulser System for the D0 Muon Upgrade Scintillation Counters", P. Hanlet *et al*, Nucl Inst and Methods A, 42372 (in press)